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IMPLICIT LEARNING: ARTIFICIAL GRAMMAR TESTING

(master's thesis)

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Abstract

The purpose of this study is to provide an analysis of the Artificial Grammar Learning Paradigm testing. This testing aims at finding out just how proficient humans are in learning structures they have never seen before and whether that ability is implicit. It includes a task in which participants were asked to find a pattern in an artificial grammar created for the purpose of this study. Based on the findings, we were able to find out more about implicit grammar learning. Language and how it is acquired has been a point of interest of numerous researchers for centuries and researching implicit learning will help us discover more about how language is acquired. As an introduction to the experiment, we will first go over the issue of first language acquisition using studies on primates. Here we will analyse theories on the origin of language and the history of thought on the topic. We will then use studies on primates and look at how similar language acquisition is between humans and primates, and what conclusions have we been able to draw based on the studies done. To delve deeper into the topic, we will provide an analysis of implicit grammar learning and give an introduction into the Artificial Grammar Learning Paradigm. It is hoped that this study will inform the reader on the topic of implicit learning and aid other researchers in their work. Even though AGL testing sheds some light on the subject matter of first language acquisition in children, it does not take into account other factors that influence such process. Further research into the area of AGL testing should take factors such as context and meaning into account.

Key words: origin of language, primates, Universal grammar theory, the innateness theory, implicit learning, implicit grammar learning, Artificial grammar learning paradigm

Sažetak

Cilj ovog rada je analiza testiranja provedenog u sklopu Paradigme učenja umjetne gramatike *(Artficial Grammar Learning Paradigm*). Ovo testiranje ima za cilj istražiti sposobnost ljudi da implicitno nauče strukture koje nikada prije nisu vidjeli. U svrhu ovog testiranja kreiran je zadatak koji od sudionika zahtijeva pronalazak obrasca u umjetno stvorenoj gramatici te smo na temelju rezultata uspjeli smo saznati više o implicitnom učenju gramatike. Pitanje jezika te način na koji se on usvaja predmet je zanimanja istraživača već stoljećima te nam istraživanje implicitnog učenja može pomoći otkriti više o načinu na koji se jezik usvaja. Kao uvod u testiranje, najprije ćemo se dotaknuti problematike usvajanja materinjeg jezika analizom

studija o primatima. Prikazat ćemo analizu teorije o podrijetlu jezika te povijest mišljenja na tu temu, a zatim ćemo na temelju studija o primatima prikazati i koje su sličnosti u usvajanju jezika između ljudi i primata, te koje smo zaključke uspjeli izvući na temelju provedenih studija. Kako bismo ušli dublje u tematiku, iznijet ćemo analizu implicitnog učenja gramatike te uvod u Paradigmu učenja umjetne gramatike. Nadamo se da će ovaj rad informirati čitatelje o temi implicitnog učenja te pomoći ostalim istraživačima u njihovom radu. Iako testiranja u sklopu AGL-a pridonose objašnjavaju problematike usvajanja materinjeg jezika kod djece, ona ne uzimaju u obzir druge čimbenike koji utječu na taj proces, poput konteksta i značenja.

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1 Introduction

The origin of language has always tackled the interest of humans, especially scientists who have devoted their academic research to this issue. The main questions regarding these issues are how language came to develop and under which circumstances, what is the nature of the human language faculty, and is it confined to humans alone. After examining all the anthropological, social and genetic evidence that is available, scientists who are interested in discovering the origin of language expanded their research to primates, our genetically closest "relatives", by conducting experiments where their ability to acquire and/or comprehend language was observed. An additional purpose of these experiments was to try to discover whether species other than humans possess a capacity for language, and if so, to which extent. Furthermore, a certain ease that is ascribed to children`s ability to acquire language without explicitly being taught its rules gave rise to some interesting theories regarding language acquisition in children. One of the most prominent ones was the Universal grammar theory proposed by Noam Chomsky, which states that humans have an inborn capacity for language, whose structure enables them to acquire grammar implicitly (Chomsky, 1972).The latter notion encouraged further research into the realm of implicit (grammar) learning, and one of its greatest accomplishments was an Artificial grammar paradigm developed by Arthur S. Reber in 1967, which aims at discovering how much of the knowledge acquired in artificial grammar experiments can be considered implicit. Moreover, Reber proposed the idea that artificial grammar experiments can be compared to natural grammar induction in children.

This paper will firstly give an overview of relevant research and discoveries in the field of language origin and its evolution. Secondly, relevant language studies on primates will be discussed, along with what the collected evidence may tell us not only about their language capacity, but also about the possible origin of language in humans. Furthermore, the Universal grammar theory as proposed by Chomsky will be explained, along with the principles of implicit learning, with focus on implicit grammar learning. Moreover, the Artificial Grammar Learning Paradigm will be discussed and it will be followed by an artificial grammar testing that was conducted for the purpose of this study. The experimental method will be evaluated and discussed in relation to natural grammar induction in children.

2 First language acquisition

2.1 The origin of language

In order to discuss the issue of first language acquisition, we must first discuss the theories of the origin of language and how modern human language developed into the complex faculty that it is today. It can be said that language is both a cultural phenomenon and the most salient distinguishing characteristic of modern Homo sapiens as a species (Carstairs, McCarthy, 2008, p. 3). Scientists from various fields of research have tried to shed light on the question of the origin of language. Firstly, anthropologists had to rely on what they could glean from skulls since tongue, lips and larynx, being soft tissue, did not survive the test of time. What they discovered was that a modern articulatory and acoustic characteristic presupposes something like a modern vocal tract, more precisely an L-shaped vocal tract with an oral cavity at the right angle to the pharynx, and with the larynx low in the neck. The L-shaped vocal tract, which is characteristically human, enabled the formation of the self-contained airway from the nose to the lungs, and quite separate from the tube, which leads from the mouth to the stomach (Carstair, McCarthy, 2008, p.4). There is no clear evidence that can tell us when the L-shaped vocal tract developed, but Lieberman proposes a theory that Neanderthals had the larynx positioned high and that this linguistic disadvantage may have been a factor in their ultimate demise (Lieberman, 2007, p. 40).

Scientists believed that this relatively sudden jump in the sophistication of human linguistic behaviour, if it had occurred, should have left immediate traces in the archaeological research in the shape of a sudden jump in the sophistication of the preserved artefacts (tools, ornaments and artwork). Although a large variety of tools and ornaments were found in Europe and Africa and could be dated back to around 40 000 years ago, it does not serve as evidence of any linguistic competence of our predecessors (Carstair, McCarthy, 2008, p.5). Scientists have tried to discover to which extent syntax would be an outgrowth of a general increase in the sophistication of the hominids mental representation of the world, including social relationships and the extent to which it is an outgrowth of some more specialized development, such as better tool-making, more accurate stone throwing, or more fluent vocalization (Carstair, McCarthy,2008, p.13). Furthermore, neurobiological evidence of language origin studies managed to situate the language faculty in the parts of the human brain known as Broca's (frontal lobe of the left hemisphere) and Wernicke's area (posterior portion of the left frontal lobe). Since the 19th century, Broca's area has been associated with language production (i.e.grammar and articulation of speech) while Wernicke's area has been associated with language comprehension. The respective areas of the human brain are connected by a large bundle of nerve fibres called the *arcuate fasciculus.* These two areas were considered the language-processing parts of the brain because initial research by Paul Broca and Carl Wernicke showed that when the damage of the aforementioned areas occurred, the language faculty was severely affected. As a result, damage to Broca's area (which results in Broca's aphasia) is evident in impaired speech production and agrammatism, while damage to Wernicke's area (which results in Wernicke's aphasia) affects language comprehension, leaving the ability to produce connected speech relatively intact (Fridriksson et al., 2015, p.1). While these two areas are considered to be the "home" of the language faculty, studies on the brain structure of apes have shown that they too have areas similar to Wernicke's and Broca's but the ability to produce language did not develop in the species (Sereno,2005, p.3). Furthermore, no area of the human brain, even Broca's and Wernicke's area, seems to be associated exclusively with language (Carstairs, McCarthy, 2008, p.4).

Finally, the linguistic evidence of language origin research proposes the theory of protolanguage. According to one of the most prominent researchers in the field, Derek Bickerton (2005), protolanguage began as a free-for-all, catch-as-catch-can mode that utilized sounds, signs, pantomime and any other available mechanism that would carry intention and meaning, and it only gradually focused on the vocal mode, due to the latter's greater utility (Bickerton, 2005, p. 512). After the first burst of brain expansion between 2 and 1, 5 million years ago, *Homo habilis* and *Homo erectus* came to replace the earlier *Australopithecus* and a second burst of brain expansion occurred within the last 300 000 years as *Homo sapiens* came to replace *Homo erectus* (Aiello, 2012, p.270). Although *Homo erectus* was capable of quite sophisticated tool making, he failed to make any significant technological or cultural advance for over a million years. They were aware of social relationships, much like present day primates are, and could represent thematic structure ("who did what to whom") mentally, but they had no reliable linguistic tool for talking about these relationships or expressing these mentally represented structures. To clarify, they could not go beyond the protolanguage phase as proposed by Bickerton (2005). In result, they were linguistically trapped throughout their lives at the two-word stage of a modern toddler (Carstairs, McCarthy, 2008, p.16). As an answer to the question of how modern humans ever got beyond this protolanguage, Bickerton's answer is that new neural connections in the brain allowed speech to be hooked up to thematic structure, which has yielded a sudden and dramatic improvement in reliability and versatility of language (Bickerton, 2005, p. 1-17). What remains unclear is why the neural connections developed when they did, rather than earlier or later (Carstairs, McCarthy, 2008, p.16).

In conclusion, numerous studies on the topic of the origin of language have been conducted throughout the years (see Rapaport, 1979, Pinker, 1990, Baron-Cohen, 1999 etc.) and it would be impossible to tackle and explain all of them. What is important for our study, however, is the fact that scientists have tried to shed some light on language evolution by studying primates. Research has shown that we share approximately 99% of our DNA with chimps and bonobos, and 98% with gorillas (Wong, 2014, p.1). These small percentages do make a substantial difference since they enable us humans to have a bipedal stance and carry out conversations about whatever comes to mind, be it real or imaginary. The question of language is of particular interest to scientists: it is biologically clear that primates cannot physically produce speech, but is it fair to deny them the entirety of the language faculty, i.e. the ability to comprehend language and have mental representation of thematic structures of the kind that underlies sentences?

2.2 Primates and language

One thing that we may be certain of when it comes to primates is the fact that they cannot talk since they do not have an appropriate vocal apparatus to produce the sound of human speech (Field, 2003, p. 94). However, the natural communication of apes may hold clues about language origins, especially because primates frequently gesture with limbs and hands, a mode of human communication thought to have been the starting point of human language evolution. Furthermore, gestural communication is virtually limited to the Hominoidea (i.e. humans and apes). Gestures were first described for chimpanzees, followed by other anthropoid apes: bonobos, gorillas and orangutans. The gestural hypothesis of language origin is further supported by differential growth of the brain and vocal apparatus, the appearance of gestural communication on human infants before speech, and the right-hand (hence left-brain) bias of both apes and human gestures. In monkeys, this area is activated during both the production and perception of gestures but not during vocalizations. It has been speculated, therefore, that the neural structures underlying manual movements in the great apes, perhaps also including tool use, are homologous with the lateralized language areas in the human brain. The *Pan* line, which includes both bonobos and chimps, splits off from the line that produced our species 6 million years ago, whereas the two ape species themselves split apart only 2 million years ago. In consequence, chimpanzees and bonobos are genetically equidistant from humans. Studying similar types of communicative signals in closely related species allows one to determine homologies, i.e., shared evolutionary ancestry. A signal that occurs in both of these apes as well as humans likely was present in the last common ancestor. An additional impetus for comparing these two ape species is the suggestion that bonobos have greater language-like ability in the vocal domain than chimpanzees, which may extend to their gestural communication (Pollick, S., de Waal, 2007, p. 8184).

The aforementioned observations encouraged a number of scientists to conduct experiments on apes, particularly chimpanzees and bonobos, not just to shed some light on the evolution of language in humans, but also to investigate the linguistic abilities of primates, i.e. to investigate the symbolisation in primates since language is, in fact, a prototypical example of human ability to learn and use symbols which convey a certain meaning (Cangelosi, 2001, p.1). Moreover, scientists who believe that primates do possess language capacity have attempted to demonstrate that they are capable of acquiring language if properly taught. They are opposing the popular theories of human language acquisition, which suggest that the ability to process syntactic information is unique to humans and reflects a novel biological adaptation not seen in other animals. (cf. Savage-Rumbaugh et al., 1993, p.4). This issue, along with the overview of the most significant findings in ape studies is briefly discussed in the following chapter.

2.2.2 Studies on primates

Over the past 80 years, researches have tried to demonstrate that the great apes (chimpanzees, gorillas, and bonobos) resemble humans in language abilities more than it had been thought possible. The first experiments on chimpanzees that were conducted in the 1930s (Gua) and then again in the 1950s (Viki) were attempts to raise the chimps alongside human children (the so-called cross-nurturing), with the inclusion of speech therapy. Gua was unsuccessful in speech production, while Viki managed to produce words such as “cup”, “papa” and “up“, but there was no clear evidence that she employed these words to refer to their English referents (Savage et.al., 1993, p. 2-6). A different approach was taken with a chimpanzee named Washoe who was the first non-human to learn to communicate using American Sign Language. Her two caretakers, Allen and Beatrix Gardner, believed that she might have a great deal more neurological control over her hands than over her vocal-laryngeal and that, if exposed to signs at an early age, she might acquire them spontaneously, as do hearing children of deaf parents. Their prediction proved to be successful since by the age of 36 months Washoe had produced 85 different signs in the appropriate contextual situations and had begun to combine them well. However, she rarely made Subject-Verb or Verb-Object combinations (Savage et al., 1993, p.6). Furthermore, a gorilla named Koko was taught a modified version of ASL named "Gorilla Sign Language" and she was reportedly able to understand more than 1000 signs of ASL. However, it is generally accepted that Koko did not use grammar or syntax and that her use of language did not exceed that of a young human child (Eysenck, 2000, p. 247).

One of the most important language experiments was conducted on a chimp playfully named Nim Chimpsky in 1979. More than 19 000 multisign utterances of an infant chimpanzee (Nim) were analysed for syntactic and semantic regularities. The purpose of the experiment was to determine whether an ape could truly create a sentence. For that purpose, since the age of two weeks, Nim was raised in a home environment by human surrogate parents and teachers who communicated with Nim and amongst themselves in ASL.As of September 25, 1977, Nim had acquired 125 signs (Terrace et. al.1979, p.892).Terrace and his colleagues wrote an influential article on their work with Nim. In *Can Apes Create a Sentence?* (1979), they strongly argued that the apes in the language experiments were not using language spontaneously but were merely imitating their trainers, responding to conscious or unconscious cues. Moreover, they suggested that Nim did not show any meaningful sequential behaviour that resembled human grammar and criticised earlier success that was accomplished with Washoe, stating that Washoe displayed the same type of imitations and interruptions as Nim (Terrace et al., 1979, p. 898). However, Terrace trained Nim using the behaviourist technique of operant conditioning, so it is not surprising that many of Nim's signs were cued. Many other researchers have used a conversational approach that parallels the process by which human children acquire language. In an experimental study, O'Sullivan and Yeager (1989) contrasted the two techniques, using Terrace's Nim as their subject. They found that Nim's use of language was significantly more spontaneous under conversational conditions (O'Sullivan and Yeager, 1989, p.317).

The early ape language studies offered little proof that apes could combine symbols into grammatically ordered sentences. Apes strung together various signs, but the sequences were often random and repetitious. Nim's series of 16 signs is a case in point: "give orange me give eat orange me eat orange give me eat orange give me you" (Terrace et. al., 1979, p. 895).

More recent studies with bonobos at the Yerkes Primate Research Centre in Atlanta have broken new ground. Kanzi, a bonobo trained by Savage-Rumbaugh, seems to understand simple grammatical rules about lexigram order. For instance, Kanzi learned that in two-word utterances action precedes object, an ordering also used by human children at the two-word stage. More important, Kanzi began creating certain patterns that may not exist in English, but can be found among deaf children and in other human languages on his own. In a recent study, Kanzi's abilities were shown to be similar to those of a 2-1/2-year-old human, Alia. Rumbaugh (1995) reported that "Kanzi's comprehension of over 600 novel sentences of request was very comparable to Alia's; both complied with the requests without assistance on approximately 70% of the sentences" (Greenfield & Savage-Rumbaugh, 1990, p. 722).

Any evidence that other primates are capable of acquiring language has important implications for theories of language acquisition by humans. If chimps can be shown to recognize semantic categories and apply syntactic patterns alike (e.g. word order), then it might suggest that they too have access to the basic principles underlying language. However, this brings up the following question: why some simplified form of language failed to emerge with chimps in the wild? One of the answers may be that chimps do have a capacity for language, but their genetic wiring did not allow the language acquisition process to occur as naturally as it did in humans (Field, 2003, p. 95). With this in mind, we can compare the training process for these chimps with the process of a human child acquiring language. The evidence from the primate studies in which chimpanzees and bonobos were observed and trained alongside human children give us an interesting insight into the process of language acquisition of a child. At some point during the language experiment, the child had surpassed an ape and his language acquisition abilities only continued to develop over time, even without proper "training", while those of the ape normally remained stagnant. Thus, it can be said that children's acquisition of language comes as a natural process and does not require any training since children simply acquire language, with its complex grammatical rules, without explicitly being told what they are. The capacity to learn implicitly complex structures from exemplars of this structure underlies many natural processes, and the natural grammar induction in children is the most striking example of the phenomenon (Poletiek, 2005, p.440). This notion is extremely important for scientists who study the acquisition of language in humans. Those who take a nativist view, such as Chomsky (1972), Cook (1991), Bloor & Bloor (1996) and others, suggest that all children are born endowed with a special language capability in the form of a universal grammar, which enables us to recognise characteristic patterns, which occur in all of the world's languages (Field, 2003, p.95). The creator of the Universal grammar theory, the MIT linguist Noam Chomsky, is also one of the strongest critics of primate language studies since he firmly holds the view that the capacity for language is reserved for humans alone (Chomsky, p.102). The Universal grammar theory that Chomsky proposed will be discussed in the following chapter.

2.3 Universal grammar theory and the innateness hypothesis

Since the 1960s the theory of grammar has come to be dominated by ideas of Noam Chomsky. In contrast to the taxonomic approach adopted by traditional grammar, Chomsky takes a cognitive approach to the study of grammar –for him the goal of linguists is to determine what it is that native speakers know about their native language that enables them to speak and understand the language fluently (Radford, 2004, p.1). In the 1960s Chomsky has drawn a distinction between competence, the fluent native`s speaker tacit knowledge of his or her own language, and performance, the actual use of language in concrete situations. In his view, grammar is concerned with competence, rather than performance:

"Consequently, our ultimate goal in studying competence is to characterise the nature of the internalised linguistic system". (Chomsky, 1972, p.19-56)

Chomsky`s ultimate goal is to devise a theory of universal grammar which generalises from the grammars of particular human internalised languages to the grammars of all possible (natural) languages (Radford, 2004, p.2). Furthermore, there are a number of criteria of adequacy, which the theory of universal grammar must satisfy. The theory of universal grammar must be universal and provide us with the tools needed to provide a descriptively adequate grammar for any and every human internalised system. In addition, the theory of universal grammar must explain the relevant properties, i.e. why grammars of human languages have the properties they do, which is also known as the criterion of explanatory adequacy. The third condition that the theory of universal grammar must satisfy is that it must provide us with technical devices, which are so limited in their expressive power that they can only be used to describe natural languages, and are not appropriate for the description of other communicative systems. One way to constrain grammar is to suppose that grammatical operations obey certain linguistic principles and that any operation, which violates the relevant principles, leads to ungrammaticality. Furthermore, Chomsky has suggested that language is a perfect system with an optimal design in the sense that natural language grammars create structures, which are designed to interface perfectly with other components of the mind, more specifically with speech and thought systems. In his view, the mechanisms that underlie linguistic competence make it possible for young children to acquire language in a remarkably short period of time, which relates to the fourth condition of the universal grammar theory – learnability, i.e. it must provide grammars that are learnable by young children in a short period of time (Radford, 2004, p.4).

Children generally produce their first recognisable word by the age of 12 months and from that point onwards, a child's productive vocabulary typically increases by about five words a month until it reaches around 30 words at the age of 18 months. During this phase, it is difficult to find any clear evidence of the acquisition of grammar, in that children do not make productive use of inflections nor combine words together to form two and three-word utterances. At around 18 months, children start to exhibit first visible signs of the acquisition of grammar. From this point on, there is a rapid expansion in their grammatical development, until by the age of around 30 months they have typically acquired most of the inflections and core grammatical constructions (Radford, 2004, p. 4-5).

Therefore, the theory of language acquisition must explain how after a long period of many months in which there is no obvious sign of grammatical development, around the age of 18 months there is a sudden vocabulary outburst and a phenomenal growth in grammatical development that takes place over the next 12 months. Chomsky proposes that the most probable explanation for the uniformity and rapidity of the first language acquisition is to hypothesize that the course of acquisition is determined by a biologically endowed innate language faculty within the brain, which provides children with a genetically transmitted set of procedures for developing a grammar based on the speech input they receive (Radford, 2004, p.4). This claim became known as the innateness hypothesis and Chomsky has offered his view as to why he believes this innate language faculty is available to children whilst acquiring grammar. Firstly, he proposes that apparent uniformity on the type of grammars developed by different speakers of the same language suggests that children have genetic guidance in the task of constructing a grammar of their native language:

"We know that grammars that are in fact constructed vary only slightly among speakers of the same language, despite wide variation not only in intelligence but also in the conditions under which language is acquired." (Chomsky, 1972, p.79)

Furthermore, the rapidity of acquisition (once the grammar spurt has started) also points to genetic guidance under which language is acquired. As Chomsky posits it:

"*Otherwise, it is impossible to explain how children come to construct grammars….under the given conditions of time and access to data."* (Chomsky, 1972, p.113)

In addition, what makes the uniformity and rapidity of acquisition even more exceptional is the fact that a child's linguistic experience is often imperfect since it is based on the linguistic performance of adult speakers, and this may be a poor reflection of their competence:

"*A good deal of normal speech consists of false starts, disconnected phrases and other derivations from idealised competence*". (Chomsky, 1972, p.158)

This last claim by Chomsky raises an interesting question about the influence that adult speakers have on children's grammar acquisition: If much of the speech input which children receive is ungrammatical because of performance errors, how is it that they can use this degeneration to develop a competence grammar that specifies how to form grammatical sentences? In his view, in much the same way as we are genetically predisposed to analyse shapes (however irregular) as having specific geometric properties, we are also genetically predisposed to analyse sentences (however ungrammatical) as having specific grammatical properties (Radford, 2004, p. 5). An additional argument Chomsky uses in support of the innateness hypothesis relates to the fact that language acquisition is an entirely sub-conscious and involuntary activity and is, additionally, relatively unguided in a sense that parents do not teach children how to talk:

"Children acquire languages quite successfully even though no special care is taken to teach them and no special attention is given to their progress."(Chomsky, 1972, p.200-201)

In summary, Chomsky's hypothesis of the language and grammar acquisition process proposes the idea that the process is sub-conscious and determined by a biologically provided innate language faculty that enables children to successfully acquire grammatical rules despite being exposed to ungrammatical input from their parents. Moreover, the innate faculty is responsible for the creation of a universal grammar that underlies any grammar of a natural human language. What is important for our study is the idea that the acquisition of grammatical rules in children is implicit since they are at no point given explicit instructions about the grammar of their natural language. This notion gave rise to multiple studies that tackled the theory of implicit learning, especially when it comes to the acquisition of grammar. To be able to delve into the issue of implicit grammar learning, we must first deal with the notion of implicit learning itself and the research already done on the subject matter, which will be done in the next chapter.

3 Implicit learning

3.1 Definition of implicit learning

Implicit learning is defined as the process by which people obtain knowledge about the structure of the world without conscious knowledge of this structure (Gomez, Schvaneveldt, 1994, p.396). It includes learning complex information in an incidental manner, without the awareness of what has been learned. Implicit learning is often viewed in opposition to explicit learning whereby people make an active attempt to decode the structure underlying examples by taking hypotheses and incorporating them into a conscious theory (Cleermans et al.1998, p. 406-407). According to Reber (1967), one of the forerunners in the field of implicit learning, there are some major characteristics of implicit learning that differentiate it from explicit learning. For instance, unlike explicit learning, implicit learning is relatively unaffected by age and IQ scores. Furthermore, there is little variation in the ability to gain implicit knowledge from person to person (Reber, 1967, p.220). Finally, he characterized implicit learning by two critical, yet simple features: (a) it is an unconscious process and (b) it yields abstract knowledge (Reber, 1967, p.220).

Reber was one of many to offer a definition of implicit knowledge and there is no agreement on a single definition. However, while there is no consensus on a single definition of the phenomenon, scientists agree that implicit learning occurs especially under incidental conditions and when the crucial information is non-salient. Furthermore, the resulting knowledge appears to be largely unconscious or nonverbalizable (Dienes et al., 1991, p.875). Implicit learning occurs on a daily basis in a variety of situations and the common denominator seems to be the ability of people to act in a certain rule like manner without being able to point out the rules that in fact govern that behaviour.

It is generally accepted that some form of implicit learning occurs. However, there is a great deal of controversy over the nature and limits of such learning. One source of controversy stems from ambiguous usage of the term “implicit” and related controversy over determining appropriate implicit and explicit tests. In some cases, “implicit” refers to non-intentional or incidental learning. In other cases, implicit refers to unconscious knowledge in memory resulting from the learning process. Such knowledge can affect performance, but is not directly available to awareness by means of deliberate access to memory (Gomez, Schvaneveldt, 1994, p. 156).

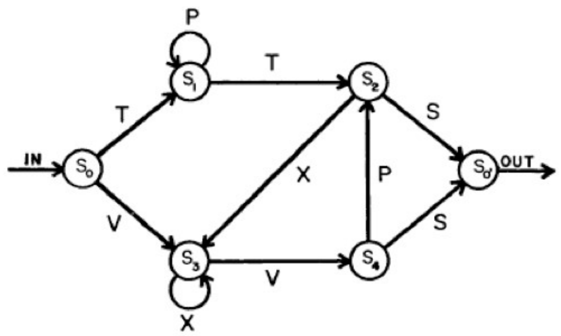
Extensive research in the field of implicit learning proposed three paradigms that have been studied in more depth: artificial grammar learning, sequence learning and dynamic system control (Cleermans et.al., 1998, p.407). Artificial grammar learning has attracted the attention of linguists and many studies in this area have been conducted in hope to clarify the role that our consciousness plays in cognitive processes such as language acquisition and the ability to recognize and produce grammatical utterances without being able to say what the rules of grammar are (Dienes et.al., 1991, p.875). Before explaining the principles of artificial grammar learning, we must briefly explain what implicit grammar learning includes.

3.2 Implicit grammar learning

Much of the implicit learning research, especially in the domain of grammar learning, focuses on identifying the mental processing and structural form taken by learning (Gomez, Schvaneveldt, 1994, p.396). In the field of linguistics, the research aims at discovering the mechanisms that govern the acquisition of grammatical rules and the degree to which these processes are available to our consciousness. The issue of implicit learning in regards to acquisition of grammar has created a debate among researchers in this field. While some scientists agree that implicit learning plays a role in language and grammar acquisition, others have suggested that implicit learning is just ordinary learning without becoming aware of the implications of that learning. Implicit learning research should therefore focus not on awareness, but on criteria such as the role of intention during learning or the conference between task demands during learning and the subsequent use of knowledge (B.W.A, Dorken, Whittlesea, 1997, p.408). Furthermore, research in implicit learning has tackled not just the question of grammar learning, but also the issue of first language acquisition in children since there is still not a definite answer to the question of how children are able to acquire the complex grammar of their native language without being explicitly taught the rules. Many linguists have tackled the issue of the first language acquisition process and the nature of the innate biological endowment, which enables humans to acquire a language so rapidly and efficiently in the first years of their life (Carstairs, McCarthy, 2008, p.1). Use of language on an everyday basis does not require explicit knowledge of grammatical rules, especially when it comes to one's native tongue. Furthermore, the psychological position cannot fully explain the acquisition of the rules of natural grammar because the sample of exemplars to which a child is exposed during the language acquisition period is demonstrably insufficient to master all these complex rules. This argument against the experience -based explanation of grammar acquisition is known as the "poverty of stimuli". (Poletiek, 2005, p. 440). The poverty of stimulus sample on which natural learners operate strengthens the argument of linguists who claim that grammar of one`s native tongue is learnt implicitly, since the capacity to learn implicitly complex structures from exemplars of this structure underlies many natural learning processes as well. In order to try to discover to what extent the acquisition of grammatical rules is implicit in its nature, cognitive psychologist Arthur S. Reber developed an Artificial Grammar Learning Paradigm whose goal is to investigate the processes that underlie human language learning by testing the subjects 'ability to learn a made-up grammar in a laboratory setting. This paradigm will be dealt with in the next chapter.

3.3 Artificial Grammar Learning Paradigm

Arthur S. Reber first developed the Artificial Grammar Learning Paradigm in 1967. He has claimed that a significant portion of knowledge is presumably unavailable to consciousness. Furthermore, he believed that this kind of knowledge is difficult to elicit in some ways; that is, classification knowledge is stored in a relatively specific database. In addition, Reber also proposed that even if implicit knowledge is found to be accessible, it may in fact not normally be used consciously (Dienes et al., 1991, p. 875). In order to try to elicit the knowledge that had been acquired consciously along with the processes required for implicit learning, Reber developed an artificial grammar-learning task. The experiment investigates whether adults can acquire the syntactic structure of a novel language without intending to and without awareness of what they have learned. The experiment constitutes an example of how the theoretical concepts and the methodological framework provided by implicit learning research can be applied to the investigation of natural language acquisition (Rebuschat et al., 2015, p.1). The standard procedure of the task includes participants who are shown a series of letter strings that follow a particular complex rule. To minimize the influence of the subjects' prior knowledge, the tasks involve complex, semantically neutral and arbitrary stimulus domain, i.e. a rule of such complexity that prevents participants from using their previously acquired knowledge in their attempts to decipher it (Cleermans et al., 1998, p.407). Participants are not initially told about the rules and are asked to complete an unrelated task first (e.g. a short-memory task). After they had completed this "training phase", subjects are told about the existence of rules, and have to then classify the next set of strings into ruleful and unruleful strings ("test phase"). For this purpose, Reber created a finite state artificial grammar, which is displayed in the figure below:



1 r

1. Ruleful strings: 2. Unruleful strings
2. VXVS VXXXS
TPTXVS TPTPS

Figure 1: The finite state artificial grammar created by Reber (1967)

In the standard AGL procedure, only positive (i.e.ruleful) strings are presented during training and subjects then have to discriminate between positive (ruleful) and negative (unruleful) strings in the test phase (Rebuschat et al., 2015, p.2). The criterion task is to judge the grammaticality of the strings i.e. probability of that string being generated by that grammar. In the artificial grammar- learning task it is assumed that learners learn in the same way, i.e. that they will base their grammaticality judgements on fragment knowledge gathered at training. That is, the "chunk associativeness" of a new string to the learning set determines its perceived familiarity. Familiarity, in turn, determines the grammaticality judgement. Unruleful strings only contain ruleful bigrams but at wrong locations (Poletiek, 2005, p. 449).

The research in the artificial grammar domain focuses on identifying the mental processing and structural form taken by learning. The suggestion that the participants actually acquire the same rules used by the researcher for generating stimuli seems ludicrous, but the question is, what do subjects actually learn? A number of hypotheses exist, including that this learning is driven by explicit knowledge of simple associations (Perruchet at al., 1991, Perruchet&Pacteau1990) or patterns in the stimuli (Dulany et.al, 1984), by positional knowledge of other bigrams (Dienes et.al., 1991), or by an implicit chunking mechanism (Matthews et al, 1989; Servan-Schrieber& Anderson, 1990).

Participants' typical classification performance, which is about 65%, indicates that they have acquired a substantial knowledge about the grammar (Dienes et al.1991, p. 875). Furthermore, participants in AGL experiments are consistently able to use knowledge that they cannot describe verbally and often express surprise when told that the material contains structure (Cleermans, 1998, p. 409). Because participants can correctly classify the grammaticality of a letter string significantly more often than what one would expect if participants were responding merely at chance levels, Reber (1967) inferred that participants are exploiting the underlying structure of the stimuli. Moreover, because participants are unable to verbalize the ruled driving their performance, this process must be implicit and non-conscious (Dienes et al., 1991, p. 875). In a theoretical account of the artificial grammar program, Reber argues that the AGL design aims at investigating grammar induction –he considers natural grammar induction to be an expression of the general skill of structure induction. The standard AGL task is designed to tap into this general skill. Hence, the AGL task is meant to represent all possible structured domains in the real world producing exemplars, including natural grammar. Experiments are designed to stimulate structure induction in general, eventually, however, the results of AGL research are meant to contribute to explaining natural grammar induction (Gomez, Schvaneveldt, 1994, p. 443).

4 Research

The purpose of this research is to examine two claims about the knowledge acquired in the artificial grammar-learning testing. Therefore, the research aims at discovering whether the participants have managed to recognize the patterns in strings that were composed according to a rule. Furthermore, the performance of participants from both Group 1 and Group 2 will be compared. Finally, the experimental method will be evaluated and discussed in relation to natural grammar induction in children. The experimental task should satisfy a number of conditions relevant for an artificial grammar study. Firstly, the structured stimuli should be novel, i.e. the subjects must be unfamiliar with the structures presented to them. Secondly, the rule system should be complex, i.e. the subjects should not be able to "crack the code" by simply testing explicit hypotheses. Furthermore, the stimuli should be meaningless and emotionally neutral. Lastly, the stimulus should be synthetic and arbitrary, because if our own assumptions about implicit learning are correct, it should appear when learning about virtually any stimulus domain, and the use of the synthetic and the arbitrary gives additional force to the argument. In addition, the criterion task is to judge the grammaticality of the string, and participants are provided with negative evidence (Reber, 1967, p. 27). Implicit learning situations typically involve the following components: exposure to some complex rule governed environment under incidental learning conditions, a measure that tracks how well participants can express their newly acquired knowledge about this environment through performance on the same or on a different task, and lastly, a measure of the extent to which participants are conscious of the knowledge they have acquired (Cleermans et.al, 1998, p. 408). All these components will be included in the artificial grammar testing described below.

4.1 Methods

Participants. The participants were 40 volunteers, randomly selected for the purpose of the experiment. Out of the 40 participants, 38 were native speakers of the Croatian language, one was a native speaker of the French language and one was a native speaker of German. Participants were randomly allocated to Group 1 and Group 2, each consisting of 20 participants. Table 1 displays general information on the participants.

Table 1. General information on the participants

WOMEN	**24**
MEN	**16**
AVERAGE AGE OF THE SUBJECTS	**25**
LEVEL OF EDUCATION	IRRELEVANT

Design. A simple artificial grammar was designed according to a rule. The rule of the grammar was constructed around the letter “S”. Four letters were chosen which can occur before this letter and four which can occur afterwards. Letters that were permitted before “S” were “V”, “L”, “O” and “E” and letters that were permitted afterwards were “P”, “A”, “B” and “D”. According to this rule, 40 strings of four letters were composed: 30 strings which follow the rule (i.e. legal strings, example: LSDP) and 10 which break the rule (i.e. illegal strings, for example BASO).

Procedure. The experiment was conducted in two phases. In the *acquisition phase,* participants were instructed to study items and in the *test phase,* participants were asked to correctly identify a string as either legal or illegal.

Acquisition phase. During the acquisition phase, 20 strings of four letters which follow the rule were displayed on a monitor. The strings were distributed one per screen and were shown to the participants one at a time. The experimenter scrolled down every two seconds onto the next string. Group 1 one was instructed to simply look at strings of letters while Group 2 was instructed to look for patterns in the strings.

Test phase. Immediately after the acquisition phase, participants from both Group 1 and Group 2 were given a sheet of paper showing, in random order, the remaining 20 strings (half legal and half illegal). Participants from both groups were asked to mark each string on the sheet as correct or incorrect (legal or illegal), even if the task seemed impossible or unclear. No further instructions were given to any of the participants.

Results. In the analysis process of the collected data, the percentage of correctness was calculated for each string. Firstly, the results from Group 1 and Group 2 were analyzed separately. The results of both groups are shown in the tables below.

Table 2. Results of Group 1

GROUP 1					
STRING	**T**	**F**	**STATUS**	**T**	**F**
ESPA	12	8	LEGAL	**60%**	**40%**
LSPD	13	7	LEGAL	**65%**	**35%**
DALS	15	5	ILLEGAL	**75%**	**25%**
OSAP	13	7	LEGAL	**65%**	**35%**
PSAL	5	15	ILLEGAL	**25%**	**75%**
ESOL	11	9	ILLEGAL	**55%**	**45%**
LOVS	5	15	LEGAL	**25%**	**75%**
LOPS	5	15	ILLEGAL	**25%**	**75%**
LEVS	7	13	LEGAL	**35%**	**65%**
OSLA	13	7	ILLEGAL	**65%**	**35%**
OELS	8	11	LEGAL	**40%**	**60%**
LOSB	10	10	LEGAL	**50%**	**50%**
SLAD	9	11	ILLEGAL	**45%**	**55%**
ESAP	16	4	LEGAL	**80%**	**20%**
SLOP	10	10	ILLEGAL	**50%**	**50%**
OSDP	6	14	LEGAL	**30%**	**70%**

BASO	8	12	ILLEGAL	**40%**	**60%**
EOLS	15	5	LEGAL	**75%**	**25%**
VESL	10	10	ILLEGAL	**50%**	**50%**
PLAS	8	12	ILLEGAL	**40%**	**60%**

Note: *T* stands for „True“, *F* stands for „False“

Table 3: Results of Group 2

Group 2					
STRING	**T**	**F**	**STATUS**	**T**	**F**
ESPA	16	4	LEGAL	**80%**	**20%**
LSPD	17	3	LEGAL	**85%**	**15%**
DALS	6	14	ILLEGAL	**30%**	**70%**
OSAP	11	9	LEGAL	**55%**	**45%**
PSAL	9	11	ILLEGAL	**45%**	**55%**
ESOL	16	4	ILLEGAL	**80%**	**20%**
LOVS	11	9	LEGAL	**55%**	**45%**
LOPS	8	12	ILLEGAL	**40%**	**60%**
LEVS	7	13	LEGAL	**35%**	**65%**
OSLA	12	8	ILLEGAL	**60%**	**40%**
OELS	9	11	LEGAL	**45%**	**55%**
LOSB	17	3	LEGAL	**85%**	**15%**
SLAD	11	9	ILLEGAL	**55%**	**45%**
ESAP	15	5	LEGAL	**75%**	**25%**
SLOP	10	10	ILLEGAL	**50%**	**50%**
OSDP	9	11	LEGAL	**45%**	**55%**
BASO	4	16	ILLEGAL	**20%**	**80%**
EOLS	16	4	LEGAL	**80%**	**20%**
VESL	10	10	ILLEGAL	**50%**	**50%**
PLAS	4	16	ILLEGAL	**20%**	**80%**

Note: *T* stands for „True“, *F* stands for „False

Once the results from each group were analysed individually, the results from both groups were compared. The data that was taken into account was the number of strings that were marked correctly either as legal or illegal by the participants. The results from both groups are shown in the table below, along with the overall percentage of correct strings for each group.

Table 4: Results from both groups compared

STRING	STATUS	GROUP 1	GROUP 2
LSPD	LEGAL	**65%**	**85%**
DALS	ILLEGAL	**75%**	**70%**
OSAP	LEGAL	**65%**	**45%**
PSAL	ILLEGAL	**35%**	**55%**
ESOL	ILLEGAL	**45%**	**20%**
LOVS	LEGAL	**25%**	**55%**
LOPS	ILLEGAL	**75%**	**60%**
LEVS	LEGAL	**35%**	**35%**
OSLA	ILLEGAL	**35%**	**40%**
OELS	LEGAL	**40%**	**45%**
LOSB	LEGAL	**50%**	**85%**
SLAD	ILLEGAL	**55%**	**45%**
ESAP	LEGAL	**80%**	**75%**
SLOP	ILLEGAL	**50%**	**50%**
OSDP	LEGAL	**30%**	**45%**
BASO	ILLEGAL	**80%**	**60%**
EOLS	LEGAL	**75%**	**80%**
VESL	ILLEGAL	**50%**	**50%**
PSAL	ILLEGAL	**60%**	**80%**
OVERALL AVERAGE		**49,7%**	**55,50%**

4.2 Discussion

The results of the artificial grammar testing indicate that adult learners are able to acquire new syntactic knowledge under incidental learning conditions, while processing sentences for meaning, without the benefit of corrective feedback and after a relatively brief exposure period. The results also show that learners are able to transfer knowledge to stimuli. Furthermore, an additional purpose of the testing was to determine whether participants from Group 1, who were not told to look for patterns in the strings, have managed to recognize the regularities in the input. The results of the testing show that they performed 5,8% worse than the subjects from Group 2. The difference in results from both groups is not a significant one, and both groups underperformed in comparison to participants in classic artificial grammar testing, whose overall percentage of correctness is about 65% (Dienes et al., 1991, p.875). However, although the research conducted in this study involved an artificial grammar testing, it did not employ as much variables as standard AGL testing, first conducted by Reber in 1967. The AGL testing conducted in this study did not employ a finite state artificial grammar as the one created by Reber that most standard artificial grammar experiments use. It did, however, require of participants to implicitly try to acquire the grammatical rule that governed the strings. Furthermore, equally to standard AGL testing, the instructions and learning exemplars were presented in such a way that discouraged conscious pattern searching or explicit hypotheses testing.

The dissociation between classification performance and verbal report is the finding that prompted Reber to describe learning as implicit (Cleermans et al., 1998, p. 408). For this reason, a verbal report was requested from participants from both groups. Participants from Group 1 and Group 2 displayed different patterns of behaviour during both acquisition and test phase. Firstly, participants from Group largely reported that they found it difficult to understand the purpose of the testing since they received relatively little instructions on what to do and what was asked of them. Therefore, their performance in the test phase was solely based on their intuition and what they assumed was required of them. Furthermore, participants from this group marked the strings as either correct or incorrect in the test phase in a faster pace than the participants from Group 2. Subjects from Group 1 did not know which route or logic to employ in their approach to the task and were left entirely to their own devices.

On the other hand, participants from Group 2 who were instructed to look for patterns in the strings had taken more precaution in the test phase. This was due to the fact that they were given more precise instructions and therefore showed more sensitivity to the mechanism they employed in their attempt to recognize the pattern. A factor that also influenced their performance in the test phase was a certain burden of expectation to perform well since they were given the specific task of deciphering the rule that governs the strings. As a result, participants from this group marked the strings as either correct or incorrect at a slower pace since the mechanisms they employed were more conscious than the ones required from Group 1.

Regardless of the group they were randomly allocated to, the majority of the participants spontaneously shared their "train of thought" after the testing phase had finished and naturally expressed their interest in the requirements and purpose of the research. While the participants from Group 1 mostly reported that they based their answers on what "sounded right", and some even considering it a memory task, feedback from Group 2 showed a more diverse range of answers and discussion of the mechanism that the subjects employed proved to be relevant to the purpose of this study.

A certain number of participants believed the task to be of mathematical nature while only a few recognized it as a task that employs recognition of a certain grammatical rule. The latter group further reported that they believed the rule in question governed the relationship between vowels or consonants and some participants believed that the rule had to do with certain letters appearing at the beginning or the end of each string. Although subjects did try to offer some explanation behind their reasoning, the vast majority of them failed to verbalize the exact rule that led them to their ultimate decision regarding the validity of the strings. Admittedly, none of the participants recognized the actual rule that was employed in composition of the strings. However, their attempt at doing so, conscious or unconscious as it may have been, contributes to the discussion of the implicit acquisition of grammar rules. The feedback from the subjects of both Groups 1 and 2 did comply with the results of previous artificial grammar learning studies. Firstly, it attributed to Reber's view that knowledge is implicit in a sense that subjects are not consciously aware of the aspects of the stimuli that led them to their decision since little or almost no instructions were given to the subjects (Reber, 1967, p.218). Most importantly, as Reber proposed, participants were not able to elicit acquired knowledge, which implies that the mechanisms that governed them throughout the task were implicit in nature (Dienes et al., 1991, p.876).

The experimental method conducted for the purpose of this study indicated that participants were able to elicit knowledge learnt under incidental learning condition to a certain extent. In absence of any explicit instructions for the artificial grammar -learning task, participants had to make grammaticality judgements based on their intuition alone i.e. what they believed to be correct on the basis of the input they had received during the training phase of the task. Therefore, it can be said that the experimental method is useful for the research of the implicit learning of novel structures. However, it is hard to determine to which extent the input influenced the grammaticality judgement, since participants were not able to verbalize their "train of thought". This seems to be a common drawback in AGL studies because the complexity of the human cognition can only be partially revealed in such experimental tasks. Although AGL testing contributes to the research of first language acquisition with its endeavour into the implicit learning of complex and novel structures, some issues need to be addressed. Firstly, the time of exposure to the stimuli might be of great importance. While participants in standard AGL testing are exposed to a stimuli for a limited amount of time i.e. only for the duration of the testing, children are exposed to the linguistic stimuli for a longer period, which might influence the acquisition of the structures they are exposed to. A child is first exposed to short and easy structures, which become more complex over time. In contrast, structures in AGL are of definite nature and hence do not allow further upgrade. Therefore, while the manner of acquisition of the structure is similar in both first language acquisition and AGL, further processing of the input is not the same. Furthermore, the acquisition of the grammar that children are exposed to is influenced by a certain linguistic goal i.e. a child will estimate whether an exemplar is useful enough to achieve a successful communication. This is absent in AGL testing since participants do not know what the goal of the testing is and the input may not be utilized to its fullest potential. Moreover, AGL testing does not take into account important factors for first language acquisition, such as context and meaning. To summarize, while AGL testing does contribute to the general research into the first language acquisition, other factors which are important for such process must be taken into account. Otherwise, we are dealing with the simplification of the grammar induction process. .

5 Conclusion

Studies on the topic of the origin of language have proposed numerous theories of how language developed into the complex faculty that it is today. Scientist have tried to shed light on this question by examining the anthropological and cultural remains of our ancestors but no definite answer was found that could account for a linguistic jump that happened in *reign* of *Homo Sapiens*. In an attempt to find an answer to this question elsewhere, scientist turned to the closest living relatives of the human species-primates. Although it is evident that primates cannot physically produce speech, natural communication of apes may hold clues about origins of language in humans, as well as evidence about their own linguistic competence. For that reason, language experiments on primates have been conducted in the last 30 years, with interesting results. While different research methods have been used in these studies, ones that gave most interesting results were the ones in which linguistic competence of an ape was compared to the ones of a human child. The studies indicated that primates are capable of recognizing semantic categories and applying syntactic patterns that underlie sentences, but in each case, linguistic competence of a child had surpassed the one of an ape. This proposes an interesting idea that children`s acquisition of language is a natural process that cannot be trained, and that it requires a certain innate capacity that enables children to learn grammar of the language implicitly.

This idea gave rise to multiple studies in the field of artificial grammar learning which aimed not only at studying the capacity to implicitly learn novel and complex structures, but also proposed that the experimental method used in these testing resembles natural grammar induction in children. For this purpose, an artificial grammar -learning task was conducted for this study. Although the finite state grammar created by Reber (1967), which is used for most standard AGL testing, was not employed in this study, the experimental task allowed participants from both groups to elicit knowledge learnt in incidental conditions to a certain extent. Furthermore, participants displayed the type of behaviours typical for subjects in standard AGL testing; they were not able to verbalize the rule that lead their performance and mostly relied on their intuition. Even though AGL testing does shed some light on the subject matter of first language acquisition in children, it does not take into account other factors that influence such process. Further research into the area of AGL testing should take factors such as context and meaning into account.

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7 Appendix

Artifical grammar learning task-training phase

1. **VLSB**

2. **SPAD**

Artficial grammar learning task-test phase

1. ESPA
2. LSPD
3. DALS
4. OSAP
5. PSAL
6. ESOL
7. LOVS
8. LOPS
9. LEVS
10. OSLA
11. OELS
12. LOSB
13. SLAD
14. ESAP
15. SLOP
16. OSDP
17. BASO
18. EOLS
19. VESL
20. PLAS